Changes in California irrigation since 1889 and impacts on temperatures

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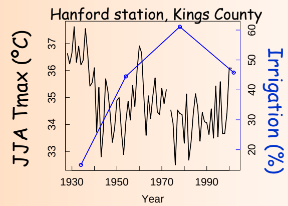
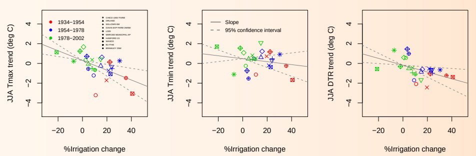
Background

The conversion of land to irrigated agriculture results in large land surface changes that can influence regional climate. Modeling studies suggest that irrigation has a significant cooling effect in California[1-2], and may explain a lack of summertime warming in temperature records[3]. We compiled available information on irrigation and temperatures over the past century to investigate whether there is, in fact, an observable effect of irrigation on temperatures.

Results

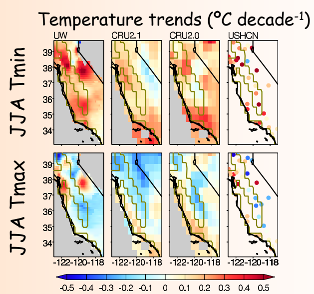
Temperature changes at USHCN stations often corresponded very closely with irrigation changes. For example, the figure on the right shows that summer daytime temperatures (Tmax) at Hanford station in Kings County decreased with the initial increase in irrigation, then warmed when irrigation growth reversed.

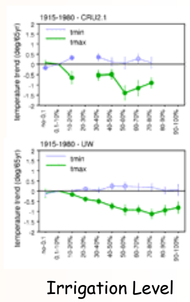




Trends in temperature and irrigation were computed for the 10 USHCN sites for 3 roughly equal time periods 1934-54, 1954-78, and 1978-2002. A comparison of irrigation changes with summer Tmax (a) Tmin (b) and DTR (Tmax-Tmin) (c) changes across all sites and time periods showed a clear negative impact of irrigation on Tmax but not Tmin. The mean estimate of the slope indicates that 100% irrigation causes a Tmax change of -5°C relative to no irrigation, in agreement with modeling studies[1-2]. The uncertainty for the slope is large, however, with a 95% confidence interval (C.I.) of -2.0 – -7.9°C (shown by the dotted lines). The mean estimate for DTR is -3.4°C per 100% irrigation, with a 95% C.I. of -0.8 – -6.1°C.

Trends for 1910-1980 for Tmax and Tmin in the gridded temperature datasets are shown to the right (UW is for 1915-1980). Comparison with the map of irrigation density (see Data section) suggests that trends for Tmax were lowest in the grid cells with the most irrigation. To quantify this relationship, we compute the difference, d(t), between temperatures in grid cells with 10-20% irrigation and reference grid cells with 0.1-10% irrigation. We then repeated this for 20-30%, 30-40%, etc. Use of differences from a reference region removed variation from large-scale forcings common to both regions. The trends in d(t) are shown for two of the gridded datasets at the far right. We found that Tmax trends were progressively cooler for increasing levels of irrigation, while Tmin trends were unaffected (solid dots are significant at $p < .01$, open dots at $p < .10$). This agrees with the results above for the station level data.

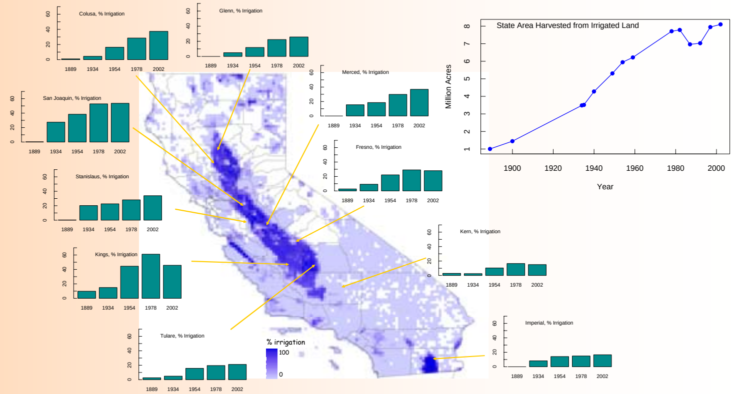




Data

Two data sources on irrigation were used: (1) A 5'x5' map of current (~1990) irrigation intensity from the FAO, shown on the right[4]; and (2) USDA census records of irrigated area for each county since 1889[5]. Data for the entire state and selected counties are shown. Total state irrigated area increased until ~1980, and has fluctuated around 8 million acres since. Counties in Northern California have experienced rapid growth in recent decades, while several other counties (e.g., Fresno, Kings, Kern) peaked in the 1970's and have decreased irrigated area in recent years. This contrast provided a gradient of space-time trends with which to evaluate irrigation's effect on temperature.

For temperature records, we used 1/8th degree gridded daily temperature since 1915 from Univ. Washington[6], 1/2 degree monthly temperature since 1910 from CRU 2.0[7] and 2.1[8], and USHCN station records[9] from 10 stations within the irrigated areas.



Conclusions

•There is observational evidence that irrigation causes significant cooling of daytime summer temperatures, with ~5°C (9°F) cooling for 100% irrigation.

•Effects on nighttime temperatures are small and insignificant.

•The rapid increase in irrigation up to 1980 likely suppressed warming effects of CO_2 increases, at local and possibly regional scales.

•Further cooling from irrigation is unlikely in the future, because irrigated area is no longer increasing in California, and there is a trend toward less water intensive crops and more efficient irrigation methods[10].

References and Acknowledgements

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